CONFERENCE OF THE EIGHTEEN-NATION COMMITTEE ON DISARMAMENT

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Working Paper listing recent Canadian scientific papers on seismological research with abstracts now available

For the convenience of members of the ENDC the titles and available abstracts on papers produced recently in Canada on seismological research are set out below. The list includes articles to which reference has already been made in document ENDC/244 of April 17, 1969, and other papers in press or contributed to the Conference on Seismological Data Exchange, Stockholm, May 1966, and the Seismic Study Group convened by the International Institute of Peace and Conflict Research (SIPRI) in Sweden, April and June, 1968:

(a) Array Research

H. Somers and E.B. Manchee: Selectivity of the Yellowknife Seismic Array, Geophys. J.R. astr. Soc., Vol. 10, p. 401, 1966. Abstract 1.

E.B. Manchee and H. Somers: The Yellowknife Seismological Array, Publ. Dom. Obs., XXXII, No. 2, 1966. Abstract 2.

D.H. Weichert, E.B. Manchee and K. Whitham: Digital Experiments at Twice Real-time Speed on the Capabilities of the Yellowknife Seismic Array, Geophys. J. R. astr. Soc., Vol. 13, p.277, 1967. Abstract 3.

D.H. Weichert: Computer Hardware and Programming Requirements for the Delay-Sum-and-Correlate Method of Processing Seismic Array Data, Seism. Series, Dom. Obs., 1967-2. Abstract 4.

F.M. Anglin and E.B. Manchee: Discrimination of Temporally Overlapping Seismic Events, Nature, Vol. 218, No. 5143, 1968. No abstract.

E.B. Manchee and D.H. Weichert: Epicentral Uncertainties and Detection Probabilities from the Yellowknife Seismic Array Data, BSSA, Vol. 58, p. 1359, 1968. Abstract 5.

K. Whitham, P.W. Basham and H.S. Hasegawa: Correlogram Discrimination Parameters from Yellowknife Seismic Array Data, Seism. Series, Dom. Obs., 1968-5. No abstract.

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K. Whitham and D.H. Weichert: Geophysical Results from Digital Processing of Yellowknife Array Signals, Travaux Scientifiques, fasc. 24, 1968. Abstract 6.

D.H. Weichert: Epicentre Determination by Seismic Arrays, Nature (in press). No abstract.

E.B. Manchee and W.D. Cooper: Operation and Maintenance of the Yellowknife Seismological Array, 1966-8, Seism. Series, 1968-2. No abstract.

D.H. Weichert and E.B. Manchee: A Photogrammetric Resurvey of the Yellowknife Seismic Array, Seism. Series, Dom. Obs., 1969-2. No abstract.

D.H. Weichert and K. Whitham: Calibration of the Yellowknife Seismic Array with First Zone Explosions, submitted to Geophys. J. R. astr. Soc. Abstract 7.

(b) Surface Wave Studies

P.W. Basham: Canadian Magnitudes of Earthquakes and Nuclear Explosions in Southwestern North America, Geophys. J.R. astr. Soc., Vol. 17, p. 1, 1969. Abstract 8.

P.W. Basham: Canadian Magnitudes of Asian Earthquakes and Explosions, submitted to Geophys. J. R. astr. Soc., 1969. Abstract 9.

(c) Signal Characteristics

P.W. Basham: Comparison of Montreal P-Wave Magnitudes from Short-Period and Intermediate Period Seismograms, Seism. Series, Dom. Obs., 1968-3. No abstract.

H.S. Hasegawa: A Study of the Effects of the Yellowknife Crustal Structure upon the P Coda of Teleseismic Events, Geophys. J. R. astr. Soc. (in press). Abstract 10.

H.S. Hasegawa and K. Whitham: Theoretical Response of a Seismograph at Yellowknife to an Underground Explosion at the Nevada Test Site, Can. J. Earth Sci. (in press). No abstract.

P.W. Basham and R.M. Ellis: The Composition of P Codas using Magnetic Tape Seismograms, BSSA (in press). Abstract 11.

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Abstract - 1

SELECTIVITY OF THE YELLOWKNIFE SEISMIC ARRAY

H. Somers and E.B. Manchee

An idealized signal, consisting of a noise-free, single-frequency infinite-duration input, is theoretically applied to the Yellowknife seismic array. A comparison of the output responses resulting from three possible signal processing techniques, viz. cross-correlation, sumall-squared, and multiple correlation, indicates that cross-correlation is the preferred technique for determining the azimuth and velocity of arrival of the incident seismic energy.

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Abstract - 2

THE YELLOWKNIFE SEISMOLOGICAL ARRAY

E.B. Manchee and H. Somers

The United Kingdom Atomic Energy Authority, in co-operation with the Department of Mines and Technical Surveys of Canada, has established a large seismological array at Yellowknife, Northwest Territories. The purpose of the array is to investigate the possibility that teleseismic detection and identification of underground nuclear tests anywhere in the world may be possible using a relatively small number of similar stations. The Yellowknife Array is a research and development facility, not an operational monitoring station.

Nineteen evenly spaced seismometer vaults are arranged in an asymmetrical cross, each arm of the cross being 22.5 km in length. The output of the single vertical Willmore Mark II seismometer in each vault is recorded on a separate track on magnetic tape. The large size of the array makes asimuth searching and velocity filtering desirable and necessary in the processing of the data. The Department of Mines and Technical Surveys is in the process of acquiring digital computing facilities which will allow the magnetic tapes to be searched for all events at twice real time speeds. In addition to the identification problem, many routine seismological problems may also be investigated by use of this new and powerful tool.

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Abstract - 3

DIGITAL EXPERIMENTS AT TWICE REAL-TIME SPEED ON THE CAPABILITIES OF THE YELLOWKNIFE SEISMIC ARRAY

D.H. Weichert, E.B. Manchee and K. Whitham

A number of experimental seismic arrays have been constructed in the past few years. One such array in the form of an asymmetric linear cross has been built at Yellowknife,

NWT, by the United Kingdom Atomic Energy Authority in collaboration with the Canadian Department of Mines and Technical Surveys. Data from the 19 individual seismometers are recorded continuously on FM magnetic tape. The analogue tape data are multiplexed into a digital computer at twice the recording speed. The system allows the formation of 168 beams by the delay and sum method: different approaches to this problem and their implications for real time processing are discussed. The correlations between the phased sums of the two lines are calculated and events are detected automatically when the correlation rises above a trigger level for a preset length of time. For each event a selection of logarithmic correlations is output in analogue form, together with other pertinent information.

The recorded data have been analysed in two modes: free search, in which the entire tape is searched by the computer; and selective search fine scan, in which events are selected visually from a helicorder record and subjected to a variety of search procedures. A 30-day free search experiment indicated that the 50% detection probability level is m4.1 ± 0.2. The location accuracy of the events detected during the 30-day experiment is of the order of 300 km in latitude and longitude and fine scan experiments have shown that this accuracy may be improved. The signal/noise ratio improvement is close to the theoretical value.

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Abstract - 4

COMPUTER HARDWARD AND PROGRAMMING REQUIREMENTS FOR THE
DELAY-SUM-AND-CORRELATE METHOD OF PROCESSING SEISMIC ARRAY DATA

D.H. Weichert

The data from the Yellowknife seismic array have been processed digitally in Ottawa since early 1966. The method used was the sum-delay-and-correlate method and required approximately 16,000 words of computer memory when conducted at twice real-time speed, because of trade-offs between memory and processing speed. For the particular configuration of the Yellowknife array, and for a sufficiently uniform crust, it is demonstrated that, with an average third generation computer with about 4 usec addition time and 24-bit word length, the data could be processed continuously at four times the recording speed. About 100 beams would be maintained, covering uniformly the third zone.

The routine formation of digital files for all detected events is not possible at four times the recording speed, unless more than one direct-memory-access channel is incorporated in the digital computer system. With two such channels, approximately one digital tape would be required per recording week. With only one channel as presently approved for purchase, digital tape formation for international data exchange is possible, but at twice real-time speed the tape utilization is only 18%.

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Abstract - 5

EPICENTRAL UNCERTAINTIES AND DETECTION PROBABILITIES FROM THE YELLOWKNIFE SEISMIC ARRAY DATA

E.B. Manchee and D.H. Weichert

Analog recording tapes from the Yellowknife seismic array have been processed digitally in Canada for over a year, with concentration on the automatic detection and epicenter location of events between 26° and 90° distance, using short period P-wave arrivals.

For the purpose of detection, signals from the individual seismometers in the two arms of the cross array are analog band-pass filtered, digitized at 20 samples/s, multiplexed into a digital computer, velocity and azimuth filtered and correlated, using an exponentially weighted integration over time with an equivalent width of 1.6s. The correlograms for up to 168 phased beams are scanned for values exceeding a present trigger level and an event is recorded when the level is passed consistently a number of times. In late 1966, during a seismically quiet period and with the array fully operational, the 50 per cent automatic detection level achieved by this method for events in the Third Zone to Yellowknife was m4.0 ± 0.1, slightly better than the level of an analog trigger operated at the station which uses the correlogram method for a single unphased beam only. The 50 per cent detection level of the Yellowknife standard station is about m4.4 and thus the array-computer automatic detection method gives about Δm0.4 improvement, which is expected from the processing method used if the noise is largely uncorrelated. No significant variations in the detection level with asimuth have yet been observed.

Approximate epicenter locations are determined from the best apparent arrival vector. The best vector is assumed to be given by the maxima of parabolas at constant azimuth and wave number interpolated between the highest values of the correlograms.

USCGS P.D.E. information is used in conjunction with the J-B tables to calculate an expected apparent arrival vector. The difference between the expected and best interpolated arrival vectors has an average deviation of about 6 ms/km. Their distribution does not suggest a simple crustal or upper mantle cause under the array station.

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Abstract - 6

GEOPHYSICAL RESULTS FROM DIGITAL PROCESSING OF YELLOWKNIFE ARRAY SIGNALS.

K. Whitham and D.H. Weichert

Results are described from the automatic digital processing of teleseismic signals from the medium aperture crossed seismic array at Yellowknife, N.W.T. Developments in the automatic processing method are described which increase the speed from that previously described. Epicentral uncertainties from a single array determination are outlined.

Intensive digital processing is described of a tape obtained by the superposition of the signals from the Early Rise chemical explosions at an epicentral distance of about 21°. The results and other observations from chemical explosions at 11° to 17° are compared with the predictions for the average upper mantle structure derived from observations of chemical explosions on the Canadian standard seismic network at long ranges. Preliminary upper mantle structural interpretations are given incorporating phase velocity data with time and distance data. The difficulties in self-consistent interpretations using velocity filtering are outlined. The best model to date requires only a very weak P-wave low velocity layer at considerable depth in the PreCambrian Shield.

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Abstract - 7

CALIBRATION OF THE YELLOWKNIFE SEISMIC ARRAY WITH FIRST ZONE EXPLOSIONS

D.H. Weichert and K. Whitham

Recordings from a crustal seismic experiment, which was conducted in the Yellowknife area in 1966, were used for calibration of the Yellowknife seismic array. In the immediate vicinity of the array the crust is found to be very uniform. A superficial layer with an intercept time of 0.172 ±0.012 s and unknown velocity is underlain by a crust with a P-wave velocity of 6.04 ±0.01 km/s near the top: assuming this velocity constant throughout the second layer, the total thickness of the crust is about 34 ±2 km. The Mohorovicic discontinuity is horizontal under the array within the resolution of this experiment and the apparent P_n velocity is 8.15 km/s. At a distance of a few tens of kilometers the crustal uniformity breaks down. The distances are such that, for most teleseismic signals, the effect of these inhomogeneities should be negligible.

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Abstract - 8

CANADIAN MAGNITUDES OF EARTHQUAKES AND NUCLEAR EXPLOSIONS IN SOUTHWESTERN NORTH AMERICA

P. W. Basham

Canadian seismograph network mean body-wave and surface-wave magnitudes are computed for 28 earthquakes and 28 nuclear explosions in southwestern North America to test the effectiveness of the surface- vs body-wave discriminant between earthquakes and explosions for purely continental paths. For the present Canadian network, the magnitude threshold of discrimination is about m4.5. A comparison is made between these and other (intercontinental) surface- vs body-wave relationships by normalizing all data to standard magnitudes. Surface-wave attenuation for intercontinental paths limits the effectiveness of the discriminant to magnitudes about 1.0 higher than the same recording techniques can achieve for intracontinental paths.

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Abstract - 9

CANADIAN MAGNITUDES OF ASIAN EARTHQUAKES AND EXPLOSIONS

P. W. Basham

A suite of 33 Asian earthquakes and 36 central Asia and Novaya Zemlya nuclear explosions are used to define the minimum detection levels in terms of surface-wave and body-wave magnitudes and the discrimination thresholds of the M versus m discriminant for the Canadian seismograph network. Under low microseismic noise conditions surface-waves can be observed for earthquakes down to m4.9 and explosions down to m5.9 for the region near the central Asia test site. For events above these magnitudes, the M versus m relationships provide reliable discrimination between earthquakes and explosions. Comparison with an intracontinental study leads to the conclusion that the discrimination threshold is limited by path effects and greater distances to events about ml.3 larger near the central Asia test site than near the Nevada test site.

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Abstract - 10

A STUDY OF THE EFFECTS OF THE YELLOWKNIFE CRUSTAL STRUCTURE UPON THE P CODA OF TELESEISMIC EVENTS

H. S. Hasegawa

The short-period P codas of seven earthquakes and four underground nuclear events recorded in the Yellowknife region of the Canadian Shield are analyzed both in the time and in the frequency domains. In the time domain, the applications of a "P-detection" filter to the earthquake events facilitates the identification of several phases (pP and sP) in the first 25 sec. of the P coda. The application of this filter to two nuclear events (originating at the Nevada Test Site) assists in the separation and in the identification of the crustal reverberations at the respective sources. In the frequency domain studies, the application of the spectral ratio test to six earthquake events resulted in poor agreement between the theoretical and the experimental spectral ratio curves; closer agreement was obtained for the nuclear events. Since the earthquake events did not possess the appropriate type of waveform for the spectral ratio test, it is not possible, at this stage, to pass judgment as to whether the crustal layering at Yellowknife fulfils the requirements of Haskell's matrix theory.

Signal-generated noise studies are based on the observation of P-generated SH and SV waves. Anomalous P-SH conversion is much less in this region than in the sedimentary basin of central Alberta. However, there are indications of appreciable anomalous P-SV conversion; the source is likely in the lower part of the crust and possibly in the upper part of the mantle at Yellowknife.

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Abstract - 11

THE COMPOSITION OF P CODAS USING MAGNETIC TAPE SEISMOGRAMS

P. W. Basham and R. M. Ellis

The short-period P codas of 41 seismic events recorded on the plains of western Alberta are examined for compressional and shear phases. A non-linear "P-Detection" polarization filter is applied to 25 seconds of the records following the P onset. Numerous compressional wave signal pulses are detected amid the codas; these include PcP and PKP phases for events at appropriate distances and the common depth phases pP and sP. The phase pP is detected on the records of 25 events, 16 of which have reported

depths shallower than 40 km. For events with pP visible at two stations, pP-P times are accurate to about ±1 second, allowing focal depth assignment to an accuracy of about ±15 km. Locally-generated shear phases are studied using particle motion plots in the vertical (vertical-radial) and horizontal planes. These are large variations in SV/P amplitude ratios for individual events at stations separated by 60 to 160 km. Anomalous SV and SH-type motions are attributed to a complex Precambrian basement.

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